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What Does Augmented Reality Mean as a Medium of Expression for Computational Artists?

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ABSTRACT

As augmented reality (AR) quickly evolves with new technological practice, there is a growing need to question and reevaluate its potential as a medium for creative expression. The authors discuss AR within computational art, framed within AR as a medium, AR aesthetics and applications. The Forum for Augmented Reality Immersive Instruments (ARImI), a two-day event on AR, highlights both possibilities and fundamental concerns for continuing artworks in this field, including visual bias, sensory modalities, interactivity and performativity. The authors offer a new AR definition as *real-time computationally mediated perception*.

AUGMENTED REALITY IN A BROADER CONTEXT

Augmented reality (AR) has seen recent resurgence with new tools, user interfaces and related algorithms. In some respects, these technologies are stabilizing (e.g. new mobile AR frameworks); however, within the arts, AR technology is arguably still in early development [1] and is just beginning to see wider use by creative practitioners. Despite this early stage of development, AR technology is becoming available to the masses in ubiquitous forms (mainly through gaming and mobile technology), and these new platforms are providing new ways of creatively altering our perception of the environment in more detailed, nuanced, multisensory, timely and perceptually believable ways than were previously possible. This is happening above a rising base level of pervasive technology as it and its data merge both "physical and mental constructs" [2].

We see computational arts as a practice centering on the creation of interactive artworks that are fundamentally algorithmic (probably digital but possibly biological, mechanical, analog, for example). In the context of expressive media for computational arts, we define AR as *real-time computationally mediated perception*. *Mediated* because there is the potential for the "Augmented" in AR to be a transformation of the environment as opposed to an overlay, as we typically see in functional AR systems (e.g. mapping apps). We understand the term *mediation* as subsuming *augmentation*. *Real-time* because AR responds to present events and builds mediations with a temporal connection to these events. *Computational* in that an algorithmic process or automaton senses the environment and creates mediations. We choose *perception* in preference to *reality* as new AR technology invites new forms of perception and sensory-situated experience, made possible through mediation that no longer privileges one reality (real or virtual) over another, instead approaching them as one environment, as one relational system.

To explore this, we map out ways in which new AR technology might be applied as a medium for creative expression. We do this through (1) building on discussions of AR as a medium and related aesthetics; (2) locating a genealogy of AR; (3) mapping out AR applications, focusing on sensory mediation and interactivity; and (4) conducting forum discussions on multidisciplinary views of AR [3].

This discussion contributes to current discourse concerning AR technology as a medium for computational artists and explores AR's virtual and physical relations and boundaries.

WHAT IS AUGMENTED REALITY? FROM APPARATUS TO SOCIAL EXPERIENCE

Early AR explorations [4–6] were predominantly formed around head-mounted display systems (HMDs), primarily for aerospace applications [7]. By 1997, Azuma [8] defined AR as a combination of three key characteristics: (1) combining real and virtual, (2) real-time interactivity and (3) 3D registration. This original conception of AR tended toward the visual but acknowledged a broader range of technology and forms of augmentation (e.g. haptic, auditory, etc.) [9–10]. It is crucial to mention that Azuma's position defining AR is based on the user's perception as opposed to a mediation of

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the environment itself: "Augmented Reality enhances a user's perception of and interaction with the real world" [11].

With the advancement of HMDs and ubiquitous mobile video technology, visual augmentation has been the dominant area for development within the field [12] as it began to cross over different practices in the arts, science and education and began to reach popular culture delivered in predominantly visual forms (e.g. gaming, advertising, navigation). In doing so, AR began to shift from apparatus to social experience [13]. This focus on visual augmentation obscures our understanding of what AR is and can do in relation to other sensory augmentations, and as a medium for broader creative expression.

THE MEDIUM AND AESTHETICS OF AR IN COMPUTATIONAL ART

Our own position on art and expression draws from the philosopher and psychologist John Dewey's discussion in *Art as Experience*:

> The poetic as distinct from the prosaic, esthetic art as distinct from scientific, expression as distinct from statement, does something different from leading to an experience. It constitutes one. . . .
>
> Objects of art are expressive . . . they are many languages. For each art has its own medium and that medium is especially fitted for one kind of communication [14].

We locate art and expression as a set of relations between experience, materials and environment—all physical, digital, symbolic—as languages from which new knowledge and new modes of communication are made possible.

AR art invites multimodal design practices (e.g. 3D graphical, interaction, user experience, interface, spatial, multimedia) and inevitably draws from other media forms [15] while inviting collaborative practice. Consequently, to think about AR as a medium is to think of a multimodal set of relations between technology and environments (both real and virtual and inclusive of participants corporeity) within a "cultural matrix" [16].

In doing so we are not limiting AR to one aesthetic within a medium-specificity but instead think of its medium as a set of relations that initially builds on Azuma's definition. The parameters are broad, but this is central to enabling AR to develop as a language for cultural expression [17].

Discussions on AR aesthetics [18], although still greatly reflecting the visual bias and heavily grounded in screen-based media genealogies (e.g. lantern slide projection, cinema), approach AR as being user-centric [19], mediated [20], a blending of virtual and physical reality [21] and interactive [22]. Boesel and Rey [23] also begin to discuss AR as an inhabited environment from which the digital and the physical "co-produce and co-construct one another," from which expression can be found in its "enmeshment." Consequently, we propose to trace a genealogy of the use of systems as aesthetics toward sensory social experiences.

Early aesthetic theorization of systems as artistic media becomes relevant to current thinking about AR. In the preconceptions and theorization of art objects toward system aesthetics, Jack Burnham states that System Esthetics is an approach to "socio-technical conditions rooted in the present" as he attempts to move away from art's object-oriented culture to a process-oriented culture [24]. Nicolas Bourriaud's Relational Aesthetics introduces art objects as part of "the realm of human interactions and its social context" [25], highlighting how art objects reside in relation to various environments (e.g. cultural, natural, synthetic) and forms of interactivity. In addition, Burnham [26] sees computation as a way to dissolve the boundary between art and the environment [27], in a sense envisioning some of AR's characteristics, leading us to interactive aesthetics, from which both physical matter and objects operate in relation to the participant's corporeity activated by actions and processes [28].

AR IN THE COMPUTATIONAL ARTS

To contextualize this discussion, we introduce some early and contemporary artworks that we consider to use AR as primary medium. These are not intended to provide a comprehensive review of artworks in this field; instead, they offer examples of varying sensory modalities, modes of artistic expression and participants' experience, reflecting Azuma's original definition and its contemporary adjustment.

Jeffrey Shaw's *Viewpoint* (1975) [29] is an early nondigital experiment where a viewing console and slide projections constructed a perceptually contiguous layer over the seen environment. Shaw continued to pioneer AR in *Virtual Sculpture* (1981) [30], where a moveable viewer layered 3D wireframe objects onto the surrounding environment. These works merged composed content with real environment and were passive installations.

Since this pioneering early work, advances in digital technology have enabled new forms of AR artwork. Mobile AR has become more popular; in it viewers use handheld device screens as a window into the real world with composed augmentations based on camera and sensor input. For example, Tamiko Thiel's *Gardens of the Anthroprocene* (2016) [31] adds a futuristic landscape in the form of sculpture to Seattle Art Museum's Olympic Sculpture Park using a mobile app. Similarly, Sander Veenhof and Mark Skwarek (2010) [32] curated a "guerilla-style" exhibition of 3D artifacts displayed virtually, inviting AR artists to display their work in the space of the Museum of Modern Art, New York.

Mobile AR has shown potential for involving new participants and locating AR as public art while bridging public and personal space. Both mobile AR and Shaw's artworks follow a layering paradigm where the virtual objects are predominantly additions to the real world. Golan Levin et al.'s *Augmented Hand Series* (2014) [33] steps beyond the layering paradigm, creating transformations of the "real" world. The participant sees a reimagined view of their hand when placed in a viewer; for example, the hand may have more or fewer digits, or a warped shape. The work is particularly interesting as it explores how AR might change participants' perception of their bodies and senses.

Mobile technology has opened up possibilities for sound-

based AR experiences, with apps such as RjDj, Inception and H__R [34]. This app series performs live reprocessing of sound environments. The apps take the form of sound and sensor-processing algorithms to be experienced at any time or place. Sound technology crosses over into new haptic possibilities. In *ListenTree* (2014) [35], a tree is excited with sound transducers; the participant can both feel the vibrations and listen to the sound using bone conduction technology.

New developments in AR technology bring together 3D graphics and spatial audio toward immersive experience. The potential of Microsoft's Hololens (2016, a holographic HMD) in an installation art environment is explored in Studio Drift's *Concrete Storm* (2017) [36]. Participants experience virtual extensions of the bases of real concrete posts that defy natural physical limitations. This was the first piece to use this new technology for a multiparticipant installation through a replicated experience across multiple headsets.

We restate that these are examples of the way in which AR has been used as a medium for artistic expression. These examples are tied in with the progression of technology, and some technologies that are either designed specifically for AR or that lend themselves to use in multisensory AR systems have seen only limited use by artists (e.g. Microsoft HoloLens, Ultrahaptics, wave field synthesis [37]). In addition, in thinking about AR aesthetics and drawing these works together, we observe the following points: (1) AR is being used to render data visualizations upon the environment, but the possibility of merging environments seems closer with audio AR and its transcendent quality. (2) Technology is lending new possibilities with regard to participants, environments and performativity, and levels of interactivity between them—in particular, when considering the role of the participants' corporeity. (3) New potential exists for increasing immersion, believability and creation of detailed and nuanced interactions. New technology and media open up novel modes of cognition [38], perception [39] and creative expression.

To think further about AR as a medium of expression for computational artists, we organized the two-day Forum for Augmented Reality Immersive Instrument (ARImI), looking at broader multidisciplinary applications in AR to inform new thinking around creative practice.

THE FORUM FOR AUGMENTED REALITY IMMERSIVE INSTRUMENTS (ARIMI)

The Forum for ARImI brought together multidisciplinary participants in discussion around constructing and deconstructing AR experiences, exploring new forms of creation and perception. Two days of discussions led to a collection of open questions concerning AR and the arts. Day one, "Mapping AR," saw presentations from participants with artistic, scientific, cultural and/or third sector backgrounds, with themes of culture, sensing, instruments and the arts. On day two, "Hacking AR," participants explored AR practically through an "unplugged" workshop where groups built and discussed hypothetical AR technology and a "plugged" workshop where groups experimented with off-the-shelf AR technology, using visual (mobile apps, HoloLens, cardboard VR), audio (mobile apps, bone conducting headphones) and haptic (tactile transducers and ultrasonic tools) materials.

QUESTIONING AR AS A CREATIVE MEDIUM

In wanting to clarify the nature and potential of AR as a creative medium, the Forum for ARImI raised a number of questions. Much discussion related to authorship and data production in AR installations, interdisciplinary collaboration, ethics and political and economic constraints. These all fully warrant critical attention. However, for the purpose of this discussion we focus on questions that build from Azuma's definition, with its perspective on perception and multimodality:

(1) In thinking about the *combination of real and virtual*, we are considering them as one environment.

How will mediations be temporally connected between participants and environment? *Will mediations be calculated from past events as well as in-the-moment events?*

(2) Real-time interactivity. Here we focus on asking how machines enable expression between the participant(s) and an AR artwork.

How is the role of the participant changing in AR artworks? *How do sensory mediation, new forms of representation and shared authorships enable creative expressions? Enable data collection? With potential for new kinds of immersive experiences, is there a need to revisit ethical considerations in interactive art?*

How will participants express themselves in AR environments? *How does the choice of technological engagement with the participant permit or limit the potential for expression (e.g. through wearable and mobile technology or altered environments)?*

(3) 3D registration, i.e. placing digital objects in a 3D environment. We interpret this in a broader multisensory context, as the way in which mediations are embedded within the environment.

What is the nature of "augmentation"? *Does "augmentation" mean layering, or could it also mean mediation (transformation, enrichment, enhancement)?*

(4) Mediated perception.

Which senses will be mediated? *How will multisensory works manage the interplay between sensory modalities?*

How might AR alter cognition? *If we follow Andy Clark and David Chalmers's* [40] *view that cognition extends into the environment, can AR then transform cognition by intervening between body and world?*

Conor McGarrigle states that "Augmented Reality is a problematic term in itself but . . . we're stuck with it" [41]. It can be useful to view AR as an area of a spectrum between experiencing the world "as is" and total immersion

in a computationally generated experience, as proposed by Paul Milgram and Fumio Kishino [42]. This original proposal took into account sensory modality; for contemporary AR in creative practice, this spectrum envelops additional dimensions: participant(s), environment, technology, interactivity and performativity.

Returning to the original question, "What does AR mean as a medium of expression for computational artists?" We have investigated the development of AR from an overlay technology toward a medium with nuanced, immersive and transformational potential. We have also shown the expansion of participants' environments, with AR becoming a shared social experience bridging public and personal spaces. New AR technology is seeing nascent use by artists, with far more potential for creative exploration.

We have suggested that centering on a contemporary understanding of AR is vital to creative practice. Within this context, we proposed to conceptualize AR as real-time computationally mediated perception. The questions identified at the ARImI forum can be used to frame further AR thinking and practice.

Moving forward, we reiterate Boesel and Rey's [43] points on AR as an inhabited environment where digital and physical "co-produce and co-construct one another," and suggest that an ecosystems approach—based on Agostino Di Scipio's work [44]—could be beneficial to creative practice. His work explores the inseparability of humans, autonomous systems and environment, and the emergent properties of this relationship within the concept of an ecosystem. While Di Scipio's work [45] focuses on sonic ecosystems, we could also see AR as inseparable from a multisensory ecosystem, inhabited by modes of sensing, modes of perceptual mediation, computational relationships between sensing and mediation, human participants and their environment. In this way, we consider AR within creative practice as a medium for creating new nuanced and fine-grained emergent aesthetic experiences.

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